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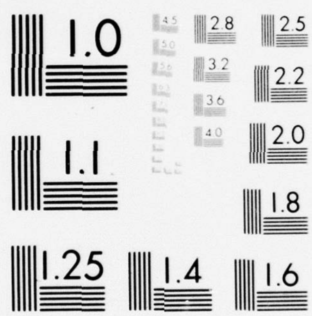

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Research and Development Technical Report

ECOM-4508

NASTRAN DATA GENERATING PROGRAMS AND ANALITICAL MODELS FOR ANALYSIS OF ANTENNA MAST AND TOWER STRUCTURES

James W. Jeter, Jr.

Research & Development Technical Support Activity

July 1977

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report is concerned with the development of data generating programs and analytical models to facilitate the structural analysis of antenna mast and tower structures subjected to static and dynamic loadings. The programs generate the data cards necessary to define the structure geometry and material properties of typical masts and towers for the NASA Structural Analysis Program (NASTRAN). The automatic data generating program for masts can be used to model any mast of constant cross section and can handle any number of cable tie points and anchor points; deform cards to duplicate cable pretension are also generated.

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as well as the force cards needed for representing a uniform wind type pressure. The automatic data generator for towers generates a series of tower stages and considers four (4) variations of tower geometry, three (3) possible base conditions and any number of sides greater than two (2). This program was designed for towers with regular generation properties and equal side lengths, but a separate program enables some variations in side length to be considered. In order to provide an economical but efficient NASTRAN model for analyzing antenna towers, three models, with varying degrees of exactness were investigated using several NASTRAN rigid formats for analysis. The capabilities and limitations of these models, with respect to the rigid formats considered, was studied.

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ILLUSTRATIONS

A. DATA GENERATING PRE-PROCESSING PROGRAMS FOR NASTRAN ANALYSIS OF ANTENNA MASTS AND TOWERS

INTRODUCTION

Computer programs were developed to generate the NASTRAN (NASA Structural Analysis) data cards necessary to define the structure geometry and material properties of typical masts and towers. These programs require a minimum of input to describe the structure and produce detailed card output which model the structure in the rigid terms that the NASTRAN computer program will accept. Automatic data generators reduce the time spent by the engineer in modeling the structure, eliminate the waiting period required to have cards hand punched, reduce the possibility of human error in the data generation process, and insure uniformity in the modeling. The data generation programs can be accessed by either the remote or the batch mode.

DISCUSSION

The automatic NASTRAN data generating program for antenna masts is capable of producing GRID cards, CBAR cards, CONROD cards (for cables), DEFORM cards (for cable pretensioning), PBAR cards and MATI cards, as well as the FORCE cards corresponding to a static representation of a wind load. The generated data cards can be applied, with some exceptions, to both static and dynamic situations. An abbreviated flow chart displaying the logic of the mast generation program is shown in Figure 1.

A typical guyed antenna mast is shown in Figure 2, and the input and generated output for the NASTRAN data deck is shown in Appendix IV. The antenna mast is modeled by the data generating program as follows:

The launcher is considered to be one CBAR element with its particular cross-sectional properties. The tube is of constant cross section and is initially divided into an inputted number of CBAR elements of equal length. Cable attachment points and any additional points are defined separately. Tie bars and cable tie points are defined to duplicate the offsetting effect of the tube thickness on attachment points. These tie points can also be used to define by input, and must be the same for each row. The distance from the base to each set of anchor points is inputted. Cables are defined as CONRODS.

It is assumed that all of the cables at a given attachment point have the same area and that there is a cable at each attachment point for each anchor row, attached equidistant from the base. Based on inputted pretensioning in pounds, DEFORM cards are developed indicating the element and

the amount of deformation corresponding to the pretensioning. If a non-zero wind velocity in miles per hour and wind direction with respect to the x-axis are inputted, FORCE cards are developed with this wind converted to an equivalent static force using empirical formulas. Numbering of the grid points and elements follows inputted values of the last grid number and element number used. A description of the inputted information is given in Appendix A.

The automatic NASTRAN data generating program for antenna towers is restricted to GRID cards, CBAR cards, PBAR cards, and MAT1 cards, since these comprise the bulk of the necessary data cards. These cards can be used for either static or dynamic situations. The program defines the tower as a series of selections stacked either on each other or on one of two base options. An abbreviated flow chart of the programming logic is shown in Figure 3. A large number of options make the data generation program adoptable to a wide variety of tower geometries.

A typical tower section is shown in Figure 4, with the corresponding input and output for the data generator given in Appendix E. The program is capable of generating any number of stages starting at a given height with grid point numbers and CBAR numbers continuing from inputted values of the last numbers used. The tower section may have three or more sides of equal length with any of the four diagonal configurations shown in Figure 5. No base or either of two base options may be used, as shown in Figure 6. The number of diagonals on a side for a stage may be inputted and grid points may be generated to space the diagonals from the top or bottom of the stage. Horizontal members may be added by an option and the basic stage geometry can be varied. Stiffening members at the top of each stage are represented by x-bracing. Separate PBAR cards are generated for verticals, horizontals, diagonals, and x-bracing. The x-bracing cross sectional properties should be made to correspond to that of whatever lateral bracing is actually present. It is assumed that all members have the same material properties. Three output options are built into the program to allow data manipulation before card punching. One special program has been written which will account for rectangular or isosceles triangular sections; other manipulative programs could be easily written. A description of the inputted information for the generation of tower data is given Appendix B; a description of the operation of the data manipulation program is given in Appendix C.

The two data generating programs can be used to describe a variety of structures or portions of structures. A number of useful combinations and approaches for modeling are described in Appendix C. Versions of all programs have been made available for both remote and batch processing. Remote accessed program names are: NASTWR, for tower data generation; MASTRN, for mast data generation; and GDMIX, for data manipulation, the corresponding batch accessed program names are: OMASTY, OMSTGN and OGDMXC. Runs producing over one hundred data cards should be done using the batch mode unless modifications are made in the remote programs.

CONCLUSIONS

Automatic data generator programs for NASTRAN have been developed which will greatly relieve the burden of structural modeling of masts and towers from the engineer and produce a more efficient NASTRAN analysis. Some hand generation is still necessary; this is particularly evident in the tower and combination models. A larger program, accounting for all likely situations (such as A-frames, general cable systems, stacking of unequal sections), is recommended for future work. The existing generators can be used as sub-programs for the large program. The capability of renumbering grid points for efficient NASTRAN runs will become necessary for the larger program; this could be effected by introducing the BANDIT renumbering program to the NASTRAN run cycle. As a final pre-processing check on the NASTRAN data deck, a capability of graphically reproducing the structure from the NASTRAN grid and element cards is needed. For optimum utilization of results, visual depiction of deflections and selective formatting of output parameters are necessary. This type of post-processing is dependent on the capabilities of the communication lines with the NASTRAN facility in use-storage of output on tape, rather than paper would be a necessity.

B. ANALYTICAL MODELS OF ECOM TOWER STRUCTURES

INTRODUCTION

The NASTRAN structural analysis program is capable of handling structures composed of a large number of elements, but only at the cost of extensive running times. A great deal of computer time can be saved with no significant reduction in accuracy if the less critical portions of a structure can be represented by a simpler model. In this study, a detailed model of a portion of an AB-585 tower and two simplified models were devised so that the effectiveness and efficiency of the simpler models could be investigated. Results obtained apply specifically only to the tower configuration considered, but can be interpreted as an indication of the behavior of other tower configurations.

DISCUSSION

The detailed AB-585 tower model and the two simplified versions, labeled models "A", "B", and "C" are shown in Figure 7. The simplification of the detailed model involved representing a portion of the tower as a mast. Model "C" retains details of the area near the antenna mounts and the base, since these areas may be critical; model "B" is detailed only at the base

Several factors affect the accuracy involved in replacing what is essentially a truss with a beam-type element. The equivalent beam cross-sectional area was set equal to the sum of the leg areas; the effect of the diagonals was ignored. The beam moments of inertia was equated to the moments of inertia of the verticals alone. Individual bar bending stiffness was not considered. The torsional stiffness was calculated from an analysis of a tower section with only a torque applied. Although the x-bracing of the detailed tower was assumed to have the same stiffness as the tower verticals, the x-bracing of both models was made very rigid to reduce the localized effect of the attachment of the mast section. The lack of symmetry in the sides of the tower cause a torque to develop when a lateral load is applied. This effect cannot be duplicated by a series of CBARS. Lateral and axial loads were applied directly to the equivalent mast for the simpler models, but were applied to the legs of the detailed models. The models were analyzed using the differential stiffness rigid format.

Numerical results for the three approaches were obtained too late for meaningful discussion in this report, but some crude comparisons can be made. Computer expense can be measured roughly by the sum of the central processing time and the periphial processing time. The totals were: Model "A" - 2500 seconds; Model "B" - 657 seconds; Model "C" - 1097 seconds. Comparisons of the maximum deflection of the simplified models with the maximum deflection of the detailed model provides a measure of the accuracy of the simpler models. The percent difference for the simpler models was about 7%; deflection values were lower for both models.

There is some indication that the difference may be attributable in part to the weak portion of the tower section where no diagonal is present - this localized behavior is not modeled into the simpler approaches.

CONCLUSIONS

Two simple models for tower analysis have been introduced. Numerical results have been generated for the differential stiffness rigid format so that the simple models may be evaluated through comparison with a detailed model. Preliminary comparisons indicate that the simpler models will provide an economical means of analysis for some tower problems. Use of the simpler models for significantly different types of behavior may require separate studies. The effectiveness of the simple models may suggest that a "D" model consisting of a linear combination of elements (a mast) should be investigated for deflection and vibrations studies. The complexity of even simple tower geometries emphasizes the need for additional work on pre-and post-processing programs.

APPENDIX A

DESCRIPTION OF DATA INPUT FOR MAST GENERATION PROGRAM

All units must be compatable unless otherwise indicated

First Line of Input:

(1) Total height

(2) Launcher height

(3) Number of elements defining tube (do not include attachment points)

(4) Number of rows of anchors

(5) Number of anchor points in each row

(6) Number of attachment points and extra points to be generated on the mast

(7) Radius of tube

(8) Wind velocity (MPH)

(9) Angle of wind direction (clockwise from X - axis in degrees)

(10) Largest grid point number previously used in structure

(11) Largest element number previously used

(12) Angle between X axis and anchor row (clockwise in degrees)

Second Line of Input:

(1) Modulus of elasticity for mast

(2) Poisson's ratio for mast

(3) Mass density for mast

Third Line of Input - same as second line, except information is for cable

Fourth Line of Input:

(1) Area of launcher

(2) I1 for launcher

(3) I2 for launcher

(4) J for launcher

Fifth Line of Input - same as fourth line, except information is for tube

Sixth Line of Input:

(1) Radial distance to first set of anchor points

(2) Radial distance to second set of anchor points

(Continue until all anchor points are accounted for)

Seventh Line of Input:

(1) Height of lowest attachment or extra point

(2) Area of cable for lowest attachment point (0 if extra point)

(3) Corresponding set of anchor points (0 if extra point)

(4) Corresponding cable pretension force (0 if extra point)

Eighth Line of Input - same as seventh but for next lowest attachment/extra point

Ninth Line of Input - same as eighth but for next lowest attachment/extra point

(Continue until all attachment/extra points are accounted for)

APPENDIX B

DESCRIPTION OF DATA INPUT FOR TOWER GENERATION PROGRAM

All Units Must be Compatable Unless Otherwise Indicated

First Line of Input:

(1) File option (1 for punching; 2, 3 are disk files)

Second Line of Input:

(1) Base option (0, 1, 2 as shown in Figure 6)

(2) Side width of tower

(3) Distance between bottom of stage and lowest diagonal

(4) Distance between bottom of stage and lowest horizontal brace

(5) Distance between top of stage and highest diagonal

(6) Slope of diagonal (degrees)

(7) Number of sides (3 or more)

(8) Number of diagonals on a side (1 or more)

(9) Number of stages (1 or more - stacked and numbered consecutively)

(10) Tower option (1, 2, 3, 4 as shown in Figure 5)

(11) Horizontal option (0 = no bars generated; 1 = all bars generated)

Third Line of Input:

(1) Modulus of elasticity of material

(2) Poisson's ratio for material

(3) Mass density for material

Fourth Line of Input:

(1) Area of verticals

(2) I1 for verticals

(3) I2 for verticals

(4) J for verticals

Fifth Line of Input - same as fourth line, except information if for diagonals

Sixth Line of Input - same as fourth line, except information is for horizontals

Seventh Line of Input - same as fourth, except information is for x-bracing

Eighth Line of Input:

If base 1 was indicated:

(1) Horizontal distance from leg to base diagonal

(2) Vertical distance from base horizontal to base diagonal

(3) Depth of base (plane of origin is at the top of the base)

If base 0 or 2 was indicated:

(1) Largest grid point number previously used (assumed to be on the centerline of the section to be generated)

(2) Largest element number previously used

(3) Heigth at bottom of stage

APPENDIX C

USE OPTIONS FOR NASTRAN DATA GENERATING PROGRAMS

The generality and flexibility built into the NASTRAN data generating programs make it possible to represent a variety of structures without significant hand punching. The more common options are described here.

A. TOWER ON BASE - Choose base option 1 or 2; provide base dimensions for option; indicate last grid point number used, last element number used, and bottom height as zero for base 2.

B. TOWER ON GROUND - Same as A with base option (2); however, pull cross bracing element cards. The central grid point at the base must remain and be restrained.

C. TOWER ON TOWER - Choose base option zero; indicate last grid point number used, last element number used, and the height at the bottom of the new stage; the last grid points used should have been at the top level of the existing tower; if not, adjustments must be made on the first few CBAR cards generated; the towers must have the same number of sides.

D. MAST ON GROUND - Straightforward application with last element and grid numbers used indicated as zero.

E. MAST ON TOWER (or mast) - Indicate last element and grid numbers used; indicate height of launcher as tower height; pull element defining the launcher and the grid card defining the base; correct the location of mast anchor points if they are not on the same level as the bottom of the mast; insure that cable connections are correct as generated; adjust x-bracing properties at the top of the tower.

F. TOWER ON MAST - Indicate option 2; enter last element and grid numbers used and base heighth; mast should end slightly below the level of the tower; they are to be connected by a CBAR element generated by hand.

G. TOWER WITH UNEQUAL DIMENSIONS - RECTANGLE - Generate tower with larger side width and corresponding diagonal angle indicated (2) as file option; regenerate with shorter side width indicating (3) as file option; load the GDMIX (OGDMIXC) file, entering as data the number of grid points and the number of elements; output will be for rectangle.

H. TOWER WITH UNEQUAL DIMENSIONS -ISOSCELES TRIANGLE - The same approach as given in G can be used; the first run should be the one which generates the ends of the unequal leg; care should be taken in determining side length for the second run which will produce the desired side length in the isosceles triangle.

APPENDIX D

INPUT AND GENERATED OUTPUT FOR TYPICAL GUYED ANTENNA MAST

The following information pertains to the mast shown in Figure 2:

```
INPUT TOTAL HEIGHT, LAUNCHER HEIGHT, NO. TUBE ELEMENTS, NO. ANCHOR ROWS
NO. PTS. IN ROW, NO. ATTACH PT., TUBE RADIUS, WIND VELOCITY (MPH)
ANGLE FROM X-AXIS (DEGREES), LARGEST GRID NO., CONNECTION NO.
PREVIOUSLY USED, X-AXIS TO ROW ANGLE
76ØØ,4Ø,1,3,2,4,3,9Ø,2Ø,Ø,Ø,4Ø
INPUT E,NU,RHO FOR MAST
?1E7,.33,2.588E-4
INPUT E,NU,RHO FOR CABLE
?3E7,.33,1E-3
INPUT LAUNCHER AREA, I1,I2,J
?5,2Ø,2Ø,4Ø
INPUT TUBE AREA, I1,I2,J
?2.25,1Ø,1Ø,2Ø
INPUT RADIAL DISTANCES TO ANCHORS
?1ØØ,2ØØ
INPUT HEIGHT, CABLE AREA, ANCHOR PT NO., AND PRETENSION FORCE
FOR ATTACH. PT.      1
?4Ø,.5,1,4Ø
FOR ATTACH. PT.      2
?2ØØ,.5,1,4Ø
FOR ATTACH. PT.      3
?4ØØ,Ø,Ø,Ø
FOR ATTACH. PT.      4
?6ØØ,1,2,4Ø
GRID      1                     Ø.ØØ        Ø.ØØ        Ø.ØØ
GRID      2                     Ø.ØØ        Ø.ØØ       4Ø.ØØ
GRID      3                     Ø.ØØ        Ø.ØØ      6ØØ.ØØ
GRID      4                     Ø.ØØ        Ø.ØØ      2ØØ.ØØ
GRID      5                     Ø.ØØ        Ø.ØØ      4ØØ.ØØ
GRID      6                     2.3Ø        1.93       4Ø.ØØ
GRID      7                    -2.82        1.Ø3       4Ø.ØØ
GRID      8                     Ø.52       -2.95       4Ø.ØØ
GRID      9                     2.3Ø        1.93      2ØØ.ØØ
GRID      1Ø                   -2.82        1.Ø3      2ØØ.ØØ
GRID      11                    Ø.52       -2.95      2ØØ.ØØ
GRID      12                    2.3Ø        1.93      6ØØ.ØØ
GRID      13                   -2.82        1.Ø3      6ØØ.ØØ
GRID      14                    Ø.52       -2.95      6ØØ.ØØ
GRID      15                   76.6Ø       64.28        Ø.ØØ
GRID      16                  -93.97       34.2Ø        Ø.ØØ
GRID      17                   17.36      -98.48        Ø.ØØ
GRID      18                  153.21      128.56        Ø.ØØ
GRID      19                 -187.94       68.4Ø        Ø.ØØ
GRID      2Ø                   34.73     -196.96        Ø.ØØ
CBAR      1      1             1           2           15          2
CBAR      2      2             2           4           15          2
CBAR      3      2             4           5           15          2
```

CBAR	4	2	5	3	15	2
CBAR	5	3	2	6	1	2
CBAR	6	3	2	7	1	2
CBAR	7	3	2	8	1	2
CBAR	8	3	4	9	1	2
CBAR	9	3	4	1Ø	1	2
CBAR	1Ø	3	4	11	1	2
CBAR	11	3	3	12	1	2
CBAR	12	3	3	13	1	2
CBAR	13	3	3	14	1	2
CONROD	14	6	15	2	Ø.5ØØØ	
CONROD	15	7	16	2	Ø.5ØØØ	
CONROD	16	8	17	2	Ø.5ØØØ	
CONROD	17	9	15	2	Ø.5ØØØ	
CONROD	18	1Ø	16	2	Ø.5ØØØ	
CONROD	19	11	17	2	Ø.5ØØØ	
CONROD	2Ø	12	18	2	1.ØØØØ	
CONROD	21	13	19	2	1.ØØØØ	
CONROD	22	14	2Ø	2	1.ØØØØ	
PBAR	1	1	5.ØØØØ	2Ø.ØØ	2Ø.ØØ	4Ø.ØØ
PBAR	2	1	2.25ØØ	1Ø.ØØ	1Ø.ØØ	2Ø.ØØ
PBAR	3	1	22.5ØØØ	1ØØ.ØØ	1ØØ.ØØ	2ØØ.ØØ
MAT1	1	.1ØØE Ø8		Ø.33ØØØ	Ø.ØØØ26	
MAT1	2	.3ØØE Ø8		Ø.33ØØØ	Ø.ØØ1ØØ	
DEFORM	3Ø	14	-Ø.ØØØ3			
DEFORM	3Ø	15	-Ø.ØØØ3			
DEFORM	3Ø	16	-Ø.ØØØ3			
DEFORM	3Ø	17	-Ø.ØØØ6			
DEFORM	3Ø	18	-Ø.ØØØ6			
DEFORM	3Ø	19	-Ø.ØØØ6			
DEFORM	3Ø	2Ø	-Ø.ØØØ8			
DEFORM	3Ø	21	-Ø.ØØØ8			
DEFORM	3Ø	22	-Ø.ØØØ8			
FORCE	1		1	16.88	Ø.93969	Ø.342Ø2
FORCE	1		2	253.13	Ø.93969	Ø.342Ø2
FORCE	1		3	236.25	Ø.93969	Ø.342Ø2

APPENDIX E

INPUT AND GENERATED OUTPUT FOR TYPICAL TOWER SECTION

The following information pertains to the tower section shown in Figure 4:

```
INPUT FILE OPTION (1-CARD OUTPUT; 2-DISK FILE HERB; 3-DISK FILE JOHN)
?2
INPUT BASE OPTION,SIDE WIDTH,DISTANCE FROM BASE TO-(A) 1ST DIAGONAL
,(B)LOWEST HORIZONTAL, DISTANCE FROM TOP TO LAST DIAG.,DIAG. ANGLE,
NO.OF SIDES,NO.OF DIAGS.,NO.OF STAGES,TOWER OPTION,HORIZONTAL OPTION
?1,49'8,6,3,8,26.Ø8,4,4,1,1,Ø
INPUT E,NU,RHO
?1E7,.33,2.588E-4
INPUT A,I1,I2,J FOR-(A)VERTICALS,(B)DIAGONALS
                    (C)HORIZONTALS,(D)X-BRACING
?.638,.212,.212,.424
?.314,.Ø81,.Ø81,.162
?.638,.212,.212,.424
?.638,.212,.212,.424
INPUT BASE DIMENSIONS- HORIZ DIST FROM VERT TO DIAG, VERT DIST
 FROM HORIZ TO DIAG, BASE HEIGHT
?15,15,25
GRID         1                  24.ØØ    24.ØØ    -25.ØØ
GRID         2                 -24.ØØ    24.ØØ    -25.ØØ
GRID         3                 -24.ØØ   -24.ØØ    -25.ØØ
GRID         4                  24.ØØ   -24.ØØ    -25.ØØ
GRID         5                  24.ØØ    24.ØØ    -15.ØØ
GRID         6                 -24.ØØ    24.ØØ    -15.ØØ
GRID         7                 -24.ØØ   -24.ØØ    -15.ØØ
GRID         8                  24.ØØ   -24.ØØ    -15.ØØ
GRID         9                  24.ØØ    24.ØØ      Ø.ØØ
GRID        1Ø                 -24.ØØ    24.ØØ      Ø.ØØ
GRID        11                 -24.ØØ   -24.ØØ      Ø.ØØ
GRID        12                  24.ØØ   -24.ØØ      Ø.ØØ
GRID        13                   9.ØØ    24.ØØ      Ø.ØØ
GRID        14                  -9.ØØ    24.ØØ      Ø.ØØ
GRID        15                 -24.ØØ     9.ØØ      Ø.ØØ
GRID        16                 -24.ØØ    -9.ØØ      Ø.ØØ
GRID        17                  -9.ØØ   -24.ØØ      Ø.ØØ
GRID        18                   9.ØØ   -24.ØØ      Ø.ØØ
GRID        19                  24.ØØ    -9.ØØ      Ø.ØØ
GRID        2Ø                  24.ØØ     9.ØØ      Ø.ØØ
GRID        21                   Ø.ØØ     Ø.ØØ      Ø.ØØ
GRID        22                  24.ØØ    24.ØØ      3.ØØ
GRID        23                 -24.ØØ    24.ØØ      3.ØØ
GRID        24                 -24.ØØ   -24.ØØ      3.ØØ
GRID        25                  24.ØØ   -24.ØØ      3.ØØ
GRID        26                  24.ØØ    24.ØØ      6.ØØ
GRID        27                 -24.ØØ    24.ØØ      6.ØØ
GRID        28                 -24.ØØ   -24.ØØ      6.ØØ
GRID        29                  24.ØØ   -24.ØØ      6.ØØ
GRID        30                  24.ØØ    24.ØØ     29.49
GRID        31                 -24.ØØ    24.ØØ     29.49
```

GRID	32		-24.ØØ	-24.ØØ	29.49	
GRID	33		24.ØØ	24.ØØ	29.49	
GRID	34		24.ØØ	24.ØØ	52.99	
GRID	35		-24.ØØ	24.ØØ	52.99	
GRID	36		-24.ØØ	-24.ØØ	52.99	
GRID	37		24.ØØ	-24.ØØ	52.99	
GRID	38		24.ØØ	24.ØØ	76.48	
GRID	39		-24.ØØ	24.ØØ	76.48	
GRID	4Ø		-24.ØØ	-24.ØØ	76.48	
GRID	41		24.ØØ	-24.ØØ	76.48	
GRID	42		24.ØØ	24.ØØ	99.98	
GRID	43		-24.ØØ	24.ØØ	99.98	
GRID	44		-24.ØØ	-24.ØØ	99.98	
GRID	45		24.ØØ	-24.ØØ	99.98	
GRID	46		24.ØØ	24.ØØ	1Ø7.98	
GRID	47		-24.ØØ	24.ØØ	1Ø7.98	
GRID	48		-24.ØØ	-24.ØØ	1Ø7.[illegible]	
GRID	49		24.ØØ	-24.ØØ	1Ø7.98	
GRID	5Ø		Ø.ØØ	Ø.ØØ	1Ø7.98	
CBAR	1	1Ø	1	5	21	2
CBAR	2	1Ø	2	6	21	2
CBAR	3	1Ø	3	7	21	2
CBAR	4	1Ø	4	8	21	2
CBAR	5	1Ø	5	9	21	2
CBAR	6	1Ø	6	1Ø	21	2
CBAR	7	1Ø	7	11	21	2
CBAR	8	1Ø	8	12	21	2
CBAR	9	2Ø	5	13	21	2
CBAR	1Ø	2Ø	6	15	21	2
CBAR	11	2Ø	7	17	21	2
CBAR	12	2Ø	8	19	21	2
CBAR	13	2Ø	6	14	21	2
CBAR	14	2Ø	7	16	21	2
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CBAR	16	2Ø	5	2Ø	21	2
CBAR	17	3Ø	9	13	21	2
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CBAR	19	3Ø	11	17	21	2
CBAR	2Ø	3Ø	12	19	21	2
CBAR	21	3Ø	1Ø	15	21	2
CBAR	22	3Ø	11	16	21	2
CBAR	23	3Ø	12	18	21	2
CBAR	24	3Ø	9	2Ø	21	2
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CBAR	27	3Ø	17	18	21	2
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CBAR	30	40	10	21	1	2
CBAR	31	40	11	21	1	2
CBAR	32	40	12	21	1	2
CBAR	33	10	9	22	21	2
CBAR	34	10	10	23	21	2
CBAR	35	10	11	24	21	2
CBAR	36	10	12	25	21	2
CBAR	37	10	22	26	21	2
CBAR	38	10	23	27	21	2
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CBAR	40	10	25	29	21	2
CBAR	41	10	26	30	21	2
CBAR	42	10	27	31	21	2
CBAR	43	10	28	32	21	2
CBAR	44	10	29	33	21	2
CBAR	45	10	30	34	21	2
CBAR	46	10	31	35	21	2
CBAR	47	10	32	36	21	2
CBAR	48	10	33	37	21	2
CBAR	49	10	34	38	21	2
CBAR	50	10	35	39	21	2
CBAR	51	10	36	40	21	2
CBAR	52	10	37	41	21	2
CBAR	53	10	38	42	21	2
CBAR	54	10	39	43	21	2
CBAR	55	10	40	44	21	2
CBAR	56	10	41	45	21	2
CBAR	57	10	42	46	21	2
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CBAR	69	20	34	39	21	2
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CBAR	73	20	39	42	21	2
CBAR	74	20	41	44	21	2
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CBAR	76	20	38	45	21	2
CBAR	77	30	46	47	21	2

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CBAR      78        3Ø        47        48        21                  2
CBAR      79        3Ø        48        49        21                  2
CBAR      8Ø        3Ø        49        46        21                  2
CBAR      81        4Ø        46        5Ø        21                  2
CBAR      82        4Ø        48        5Ø        21                  2
CBAR      83        4Ø        48        5Ø        21                  2
CBAR      84        4Ø        49        5Ø        21                  2
PBAR      1Ø      5Ø          Ø.638Ø     Ø.21     Ø.21     Ø.42
PBAR      2Ø      5Ø          Ø.314Ø     Ø.Ø8     Ø.Ø8     Ø.16
PBAR      3Ø      5Ø          Ø.638Ø     Ø.21     Ø.21     Ø.42
PBAR      4Ø      5Ø          Ø.638Ø     Ø.21     Ø.21     Ø.42
MAT1    5Ø         .1ØØE Ø8            Ø.33ØØØ Ø.ØØØ26
```

Begin

Input mast description

Define mast nodes in order of
height; define wind forces

Define attachment point nodes in order of
height; separate true from artificial attachment pts

Sort all nodes in order of height; account
for duplication when mast and attachment
nodes are very close

Define all true attachment pts in order of height

Define cable size reference for each attachment pt

Define mast elements in order of height

Define anchor nodes

Define cable tie points, cable tiebars, cable elements,
cable pretension for each attachment point

Punch NASTRAN data cards

End

FIGURE 1 FLOW CHART OF MAST GENERATION PROGRAM

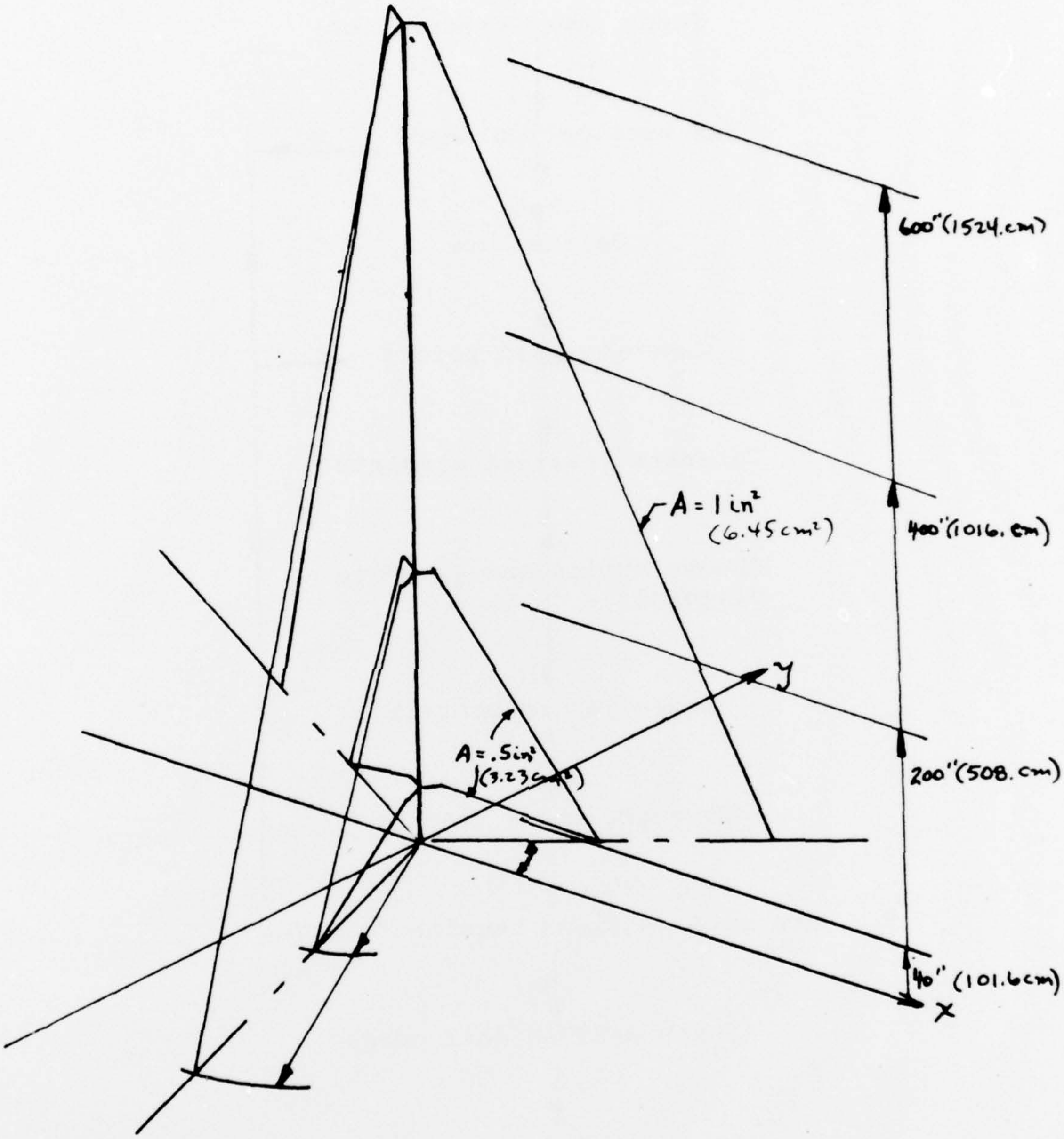


FIGURE 2: TYPICAL GUYED ANTENNA MAST

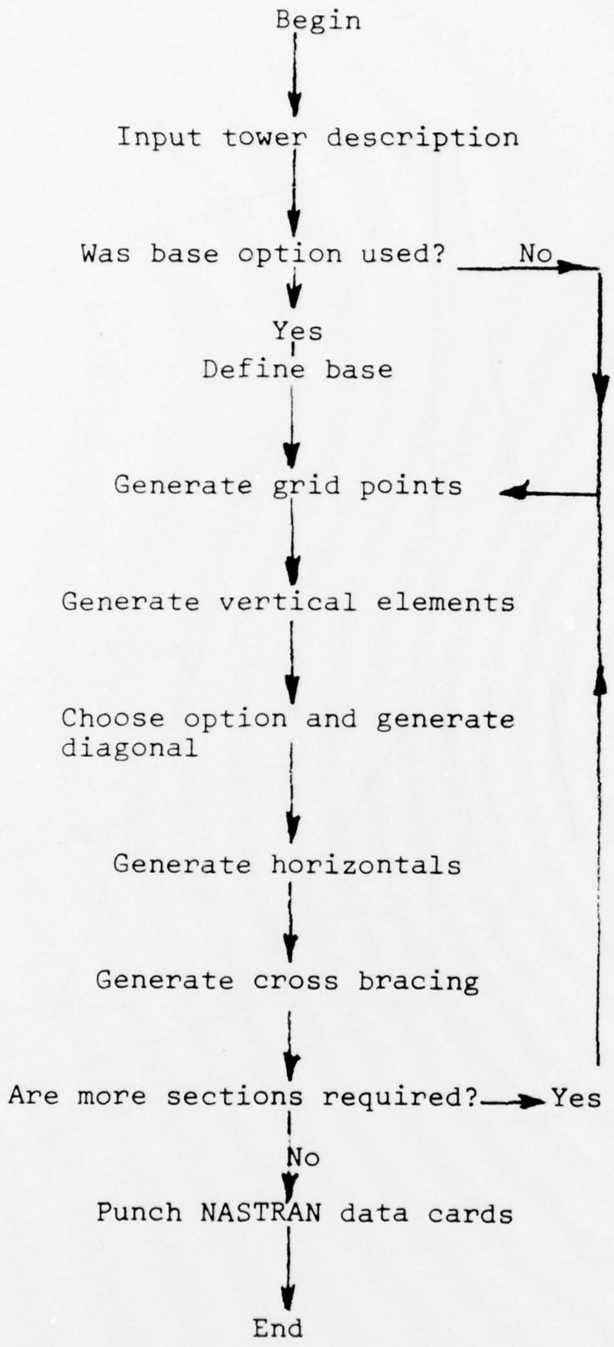


FIGURE 3 FLOW CHART OF TOWER GENERATION PROGRAM

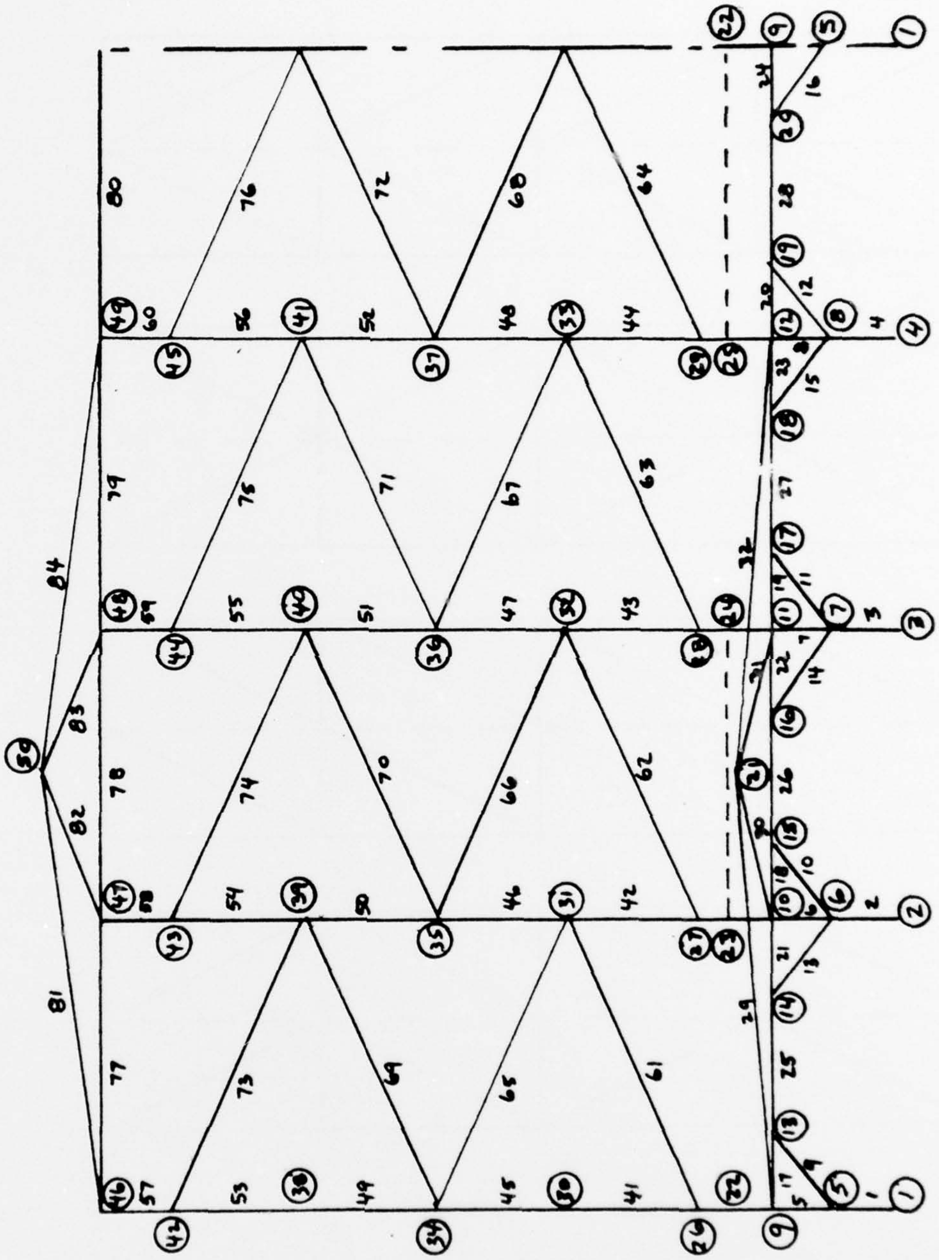


FIGURE 4 TYPICAL TOWER SECTION (UNFOLDED)

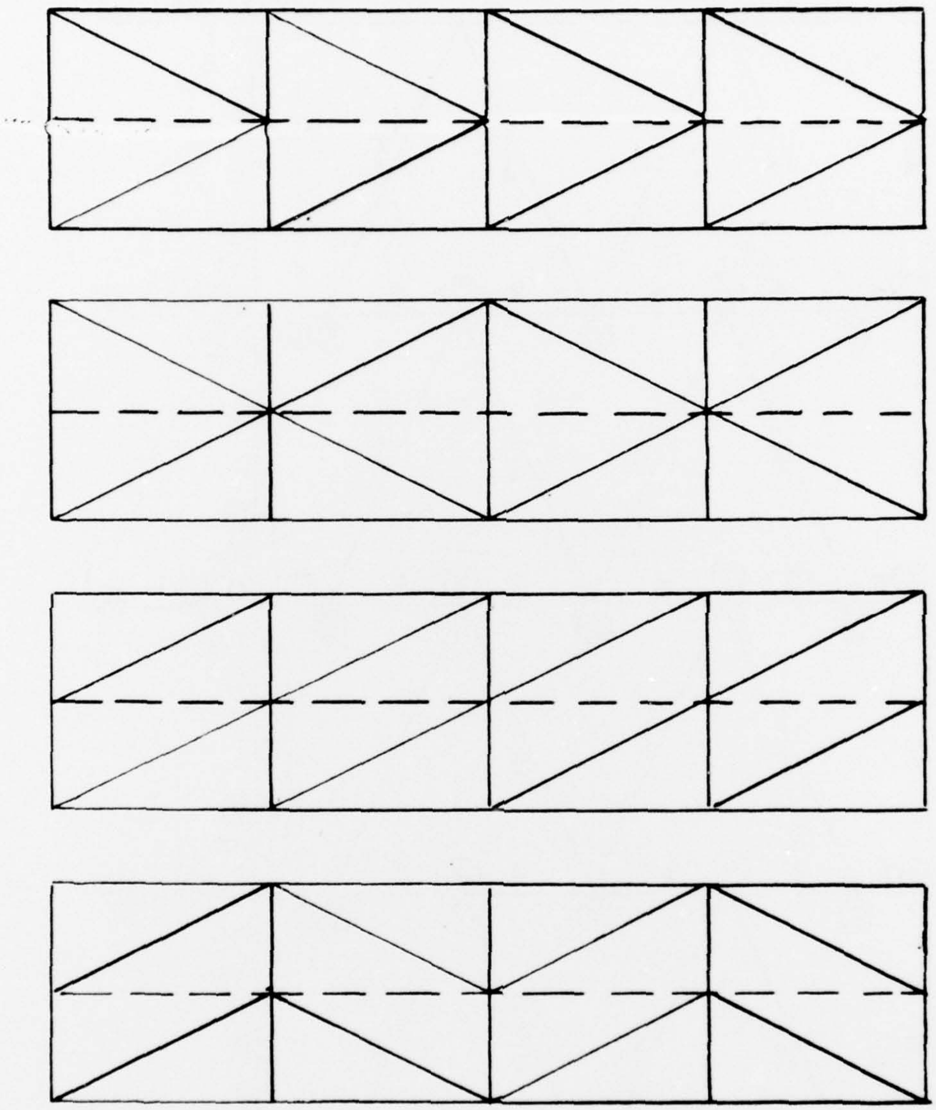
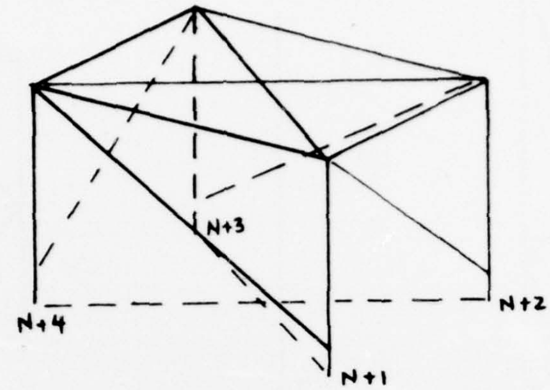
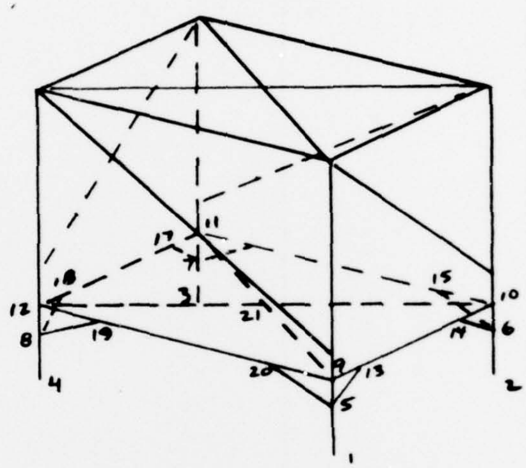


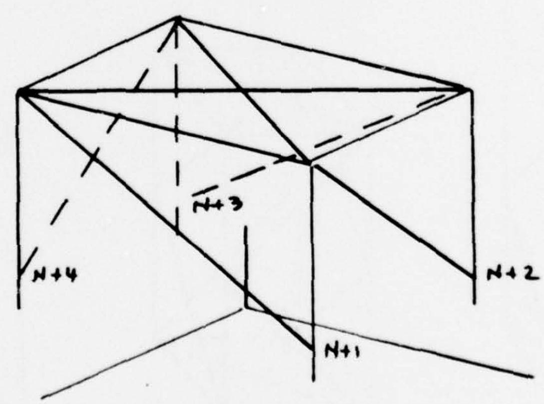
FIGURE 5 DIAGONAL OPTIONS FOR TOWER SECTIONS (UNFOLDED)



OPTION (2)



OPTION (1)



NO BASE (0)

FIGURE 6   BASE OPTIONS FOR TOWER SECTIONS

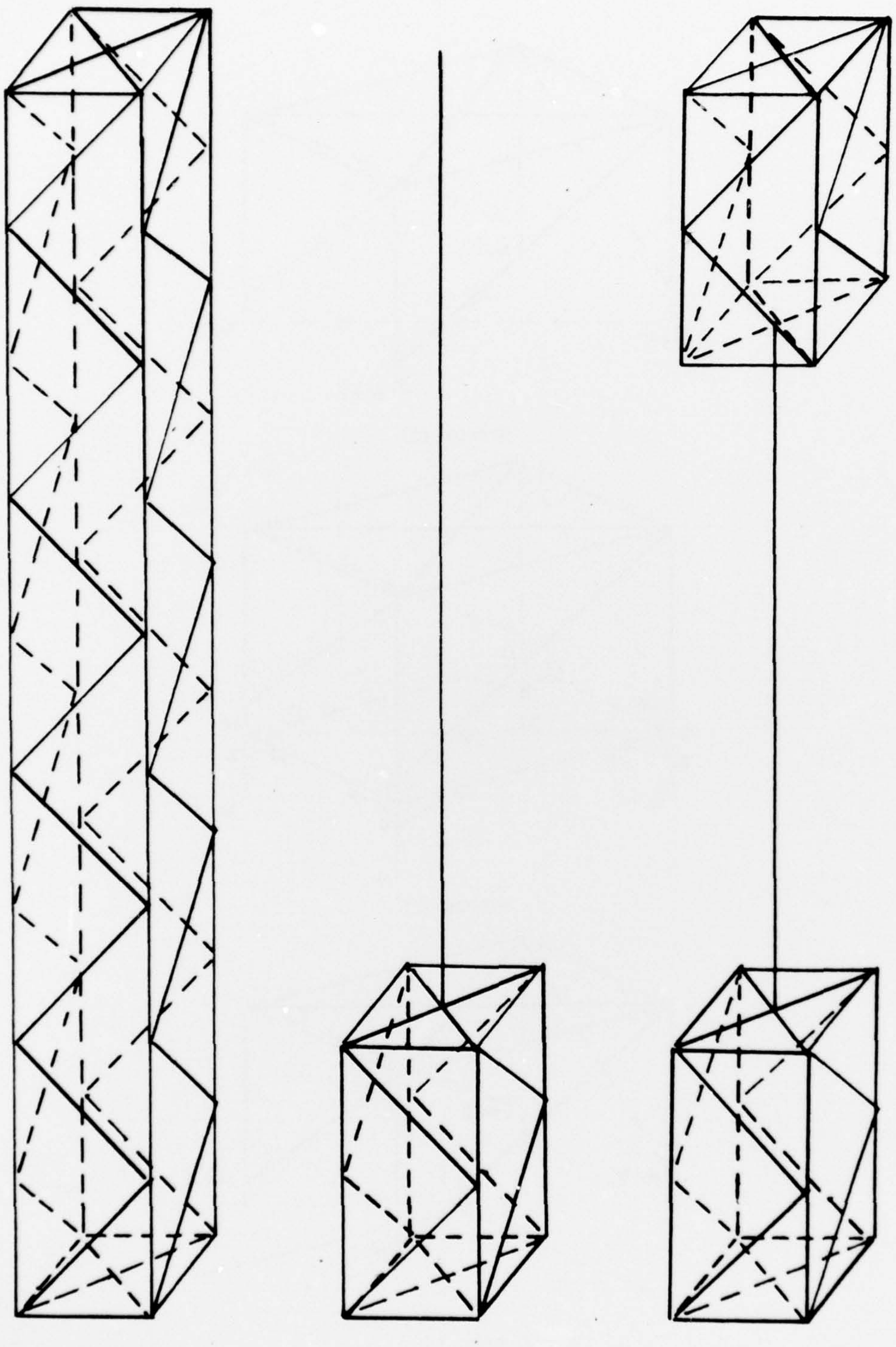


FIGURE 7 ANALYTICAL MODELS OF ANTENNA TOWERS